FRACTIONAL FREQUENCY STABILITY OF RADIO LINKS THROUGH THE SOLAR WIND AND TROPOSPHERE

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Radiowave phase scintillation caused by propagation through the solar wind is an important–sometimes limiting–noise process for many radio science observations. Spacecraft measurements of phase scintillation are considered here in this "scintillation-as-noise" context, rather than as a diagnostic of the interplanetary medium. The objective is to quantify this noise process for use in experiment feasibility studies and in error budget construction.

Measured S- and X-band radiowave phase scintillation on both "one-way" (spacecraft-to-earth) and "two-way" (earth-spacecraft-earth, where the spacecraft coherently transponds the uplink signal) are presented here in terms of the fractional frequency fluctuations they impose on the radio link. These Allan variance measurements are given as functions of sun-earth-spacecraft (elongation) angle. Phase noise is dominated by charged particle scintillation at S-band; observations at X-band, made sufficiently far from the sun, also have a significant contribution from the troposphere. Using X-band (Mars Observer and Mars Global Surveyor) data taken in the antisolar hemisphere, the different transfer functions of solar wind and tropospheric phase scintillations to two-way data can be used to decompose, approximately, the total phase variability into separate contributions from plasma and troposphere. The resulting plasma scintillation levels agree with independent dual-frequency spacecraft measurements and the tropospheric noise levels are consistent with those determined independently from water vapor radiometers.

The data can be modeled to predict propagation noise levels in the ecliptic for high-precision radio science and radio astronomy investigations as a function of elongation angle. As an example of a limiting case, spacecraft Doppler searches for gravitational waves are conducted when the spacecraft is near solar opposition to minimize plasma scintillation noise. The propagation noise budget for the Ka-band Cassini gravitational wave experiment will be presented. In particular, the plasma scintillation noise level for this experiment (two-way Ka-band observations at elongations greater than 160°) will have a level $\sigma_y(\tau = 1000\ sec) \approx 9 \times 10^{-16}$.

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